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THE NORCIA EXPERIMENT

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Abstract

A high gradient X band accelerating structure has been fabricated with the electroforming process . Low level RF measurements are in perfect agreement with the design predictions. A promising proposal in order to get a irises cooling is described, too. The high power RF tests are in progress at SLAC.

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1 Aim of the experiments

The NORCIA Group research activity is dedicated to the studies and construction of SW (standing wave) linear accelerating structures with modern approach working at 11.424 GH in order to maximize the RF (radio-frequency) performance.

In the frame of the collaboration with INFN-LNF, SLAC (USA), KEK (Japan) and UCLA (Los Angeles) we are working closely on design studies, fabrication and high power operation of X-band accelerating structures. The activity is devoted to the research and development (R&D) of key components for existing accelerators and for the next generation of accelerators. An intense technological activity is committed to making X-band accelerating structures with new materials and manufacturing techniques including single and multi-layer surfaces with precision-controlled properties. In order to determine the maximum sustainable gradients in normal conducting RF powered particle beam accelerators operating at X-band with extremely low probability of RF breakdown, the NORCIA group has designed and fabricated at INFN-LNF two electroformed (or hard) 11.424 GHz high gradient electroformed structures coated with Au-Ni and different roughness. The related RF electromagnetic characterizations at room temperature have been carried out, too. Among the others, investigations and tests of molybdenum coatings are also in progress.

2 Introduction

Technological advancements are strongly required to fulfill demands oh new accelerators devices with highest accelerating gradients reliability for the future collider [1]-[2]. An intense technological activity is therefore committed to making X-band accelerating devices, using hard structures, different materials and methods. To upgrade performances of X-band Linacs at 11.424 GHz many resources are devoted to achieve higher accelerating gradients with extremely low probability of RF breakdown and at the same time obtain the highest possible reliability. In the framework of a large collaboration among SLAC (USA), KEK (Japan), UCLA (Los Angeles) and INFN-LNF, our laboratories have been involved in the design, manufacture and test of short high power standing wave (SW) sections operating at 11.424 GHz. Since the breakdown phenomenon is an open problem, a dedicated research and development on this field has been launched within the linear-collider community. Collaboration on X-band high gradient research and related accelerator technologies, will allow to further advance the X-band technologies and benefit from some important accelerator related projects in the world.In order to improve the higher power performance of the X-band structure in terms of the accelerating gradient, the use of the materials with a high tolerance to surface fatigue due to the pulsed heating effects (materials with a higher fusion point) and to avoid the fabrication of soft devices as done in conventional brazing, are required [2],[3],[4],[5],[6]. So, in the framework of the collaboration with INFN-LNF, SLAC (USA), KEK (Japan) and UCLA (Los Angeles) in order to increase the accelerating gradient of RF cavities working at higher frequencies we decided to investigate alternative technological approaches to the standard ones as the electroforming, molybdenum sputtering on copper, electron beam welding and coatings made with a multi-layers approaches. Because electroforming is a very attractive technique to manufacture compact structures avoiding the soft brazing while maintaining mechanical properties and high vacuum requirements, two electroformed SW structures at 11.424 GHz coated with Au-Ni and different roughness have been fabricated by INFN-LNF. In addition, an extensive R&D activity concerning molybdenum coatings is also in progress. The molybdenum films were grown by RF magnetron sputtering technique on glass and sapphire substrates at room temperature. The sputtering parameters were optimized specifically addressing the growth of oxygen free Mo layers. The characterization of the chemical properties of the coated film has been carried out at the Diamond Light Source (UK) with the XANES (X-ray Absorption Near Edge Structure) and the XRD (X-Ray Diffraction) techniques.

3 Electroformed Au-Ni structures RF low-level measurements

The main cell dimensions and the mechanical drawings of the SW structures are reported in [2][3][6][7]. The SW devices have three cells fed by a circular waveguide. The central cell has a twice higher gradient while the adjacent cells are used to match the RF power from the input circular waveguide. The mode excited to test the structure is the π-mode. With this arrangement breakdowns occur predominantly in the high gradient cell while the two other cells have surface conditions unperturbed by the breakdowns [2,3,4]. Table 1 reports the relevant RF parameters measured at SLAC at room temperature of the Au-Ni electroformed structure. Figures 1 show the electroformed structure with a 70 nm roughness for the low level RF determination and the longitudinal field profiles of the π, π/2 and 0 mode characterizations.

Table 1.

Mode	Frequency [GHz]	Beta	Q_0	Q_{ext}	Q_l
0	11.2692	2.64	7090	2688	1949
π/2	11.3214	2.58	6621	2561	1847
π	11.41454	0.659	5786	8774	3486

The working π mode is about ˜9 MHz off which is fine considering that the measurements has been carried out with un-tuned devices. Because the corresponding quality factor $Q_0$is a poorer than excepted, investigations are in progress in order to understand the behavior. However its electric field profile on axis shows a good matching at the nominal RF frequency of $\sim$ 11.424 GHz with the maximum field intensity in the central cell with respect to the side ones. Similar results have been obtained also for the other one electroformed structure with a 10 nm roughness. In particular, the two structures gave a resistivity about 2.5-3 than the Cu one. Additional tests on dedicated prototypes are in progress in order to improve the conductivity of the Au deposited film as a function of the mandrel's shape. The next goal is also to evaluate the possibility to extend this process to include built-in cooling channels in the irises.

4 Molybdenum coatings

Copper coated by molybdenum via sputtering under vacuum is another promising approach to increase the accelerating gradient of RF cavities working at high frequencies. Recently [8] [9] [10][11] we presented structural and electronic characterization of Mo coatings obtained via the sputtering method and annealed up to 600 ^{o}C. This method is a promising approach to obtain homogeneous Mo coatings suitable to increase performances of RF cavities working at high frequencies. We combined FIB imaging to visualize at high spatial resolution the morphology of Mo films and to accurately measure their thickness, with transport experiments to measure the resistivity, while XRD and XAS were used to evaluate the degree of crystallinity, identify different ordered phases and probe local structure and electronic properties. Dedicated RF devices with Mo coatings have been already manufactured but still a lot of work is necessary to achieve the performances required at high power. A full characterization of the conductivity properties of optimized Mo coatings is in progress to identify reliable procedures capable to produce these highly demanding films. Existing results are promising and further enhancements of the conductivity are probably achievable tuning the synthesis and post treatment processes of Mo coatings.

5 Conclusions and future activity

Two electroformed (or hard) SW accelerating structures have been realized with the electroforming processes and tested at room temperature. The experimental results of both structures are in agreement with the design estimations. A structure has been just installed at SLAC in order to carry out the high power tests. In the meantime studies on the multilayer deposition are also in progress. In addition, a couple of dedicated prototypes (single cell) have been fabricated in order to investigate how to increase the resistivity of the gold deposition. A full characterization of conductivity properties of optimized coatings achieved with new manufacturing and characterization methods are strongly required to identify reliable procedures for such demanding films.

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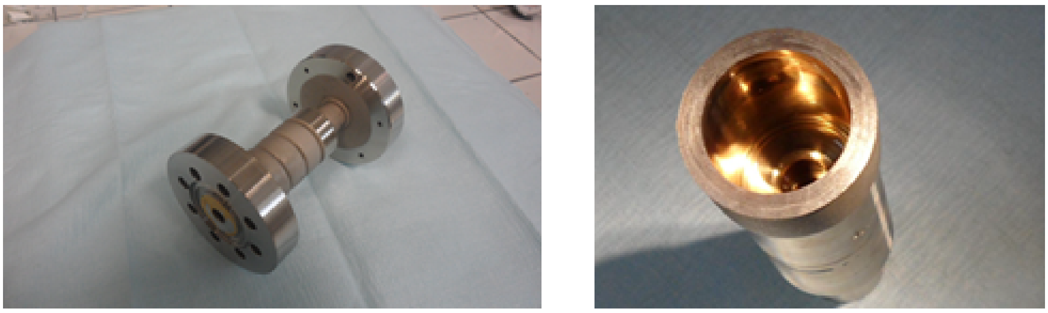

Figure 1: Left: Final X-band structure. Right: its cross section after removal of mandrel

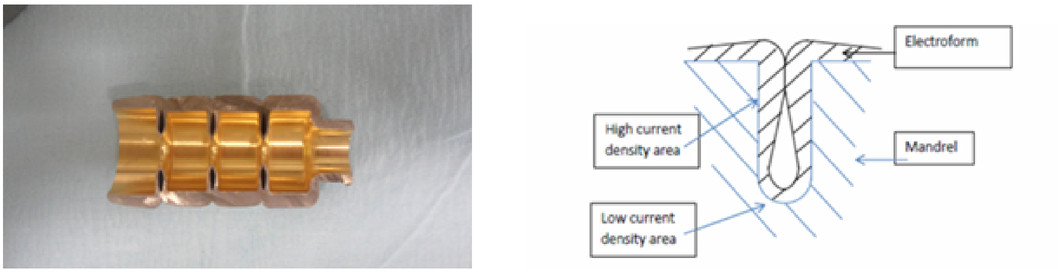

Figure 2: Open channel in the irises visible in a sectioned structure.

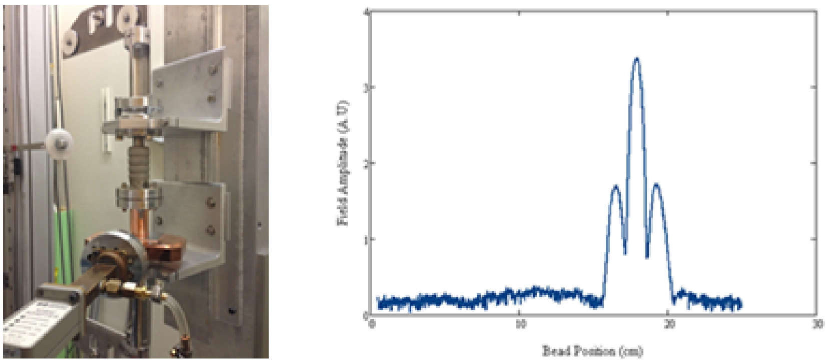

Figure 3: Left: Au-Ni electroformed structure. Right: π - mode, on axis field profile

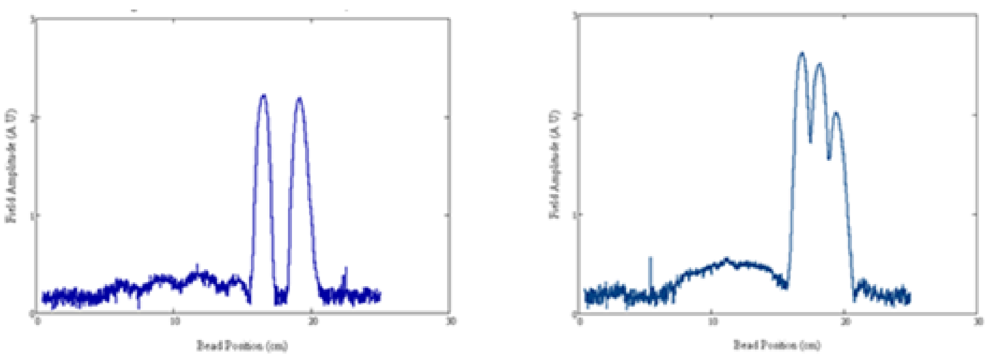

Figure 4: Left: $\pi/2$ mode, on axis field profile. Right: Mode 0, on-axis field profile